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Empirical Analysis of the Effects of Renewable Energy Consumption on Gender Inequalities in Southern Africa

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ABSTRACT

The shift to renewable energy presents a rare opportunity for sustainable improvement of socio-economic outcomes for women and reduction of gender inequality while limiting the negative impacts of climate change especially in developing countries. This study analyses the effects of renewable energy consumption on gender inequality using robust fixed effects panel regression methodology, the UNDP's Gender Inequality Index and World Bank's development indicators for the period (2002-2021). The analysis explores both linear and non-linear effects and the results reveal that renewable energy consumption has a positive relationship with gender inequalities in the selected Southern African countries. The positive coefficient suggests that the benefits of the clean energy shift are unevenly distributed because higher gender inequality Index values indicate increased gender inequality. However, this effect diminishes as clean energy consumption increases. These results are contrary to expectations that energy transitions provide socio-economic pathways for inclusive economic development. Which suggests that that renewable energy expansion may be contextual and reinforce existing gender inequalities in some regions. Based on the findings, there is urgent need for the prioritisation of gender sensitive renewable energy expansion and full participation of women in energy initiatives as Southern African nations move towards clean energy consumption.

Keywords: Climate Change, Gender Inequality, Renewable Energy, Sustainability
JEL Classifications: Q01, Q56, D63

1. INTRODUCTION

Gender inequality remains a persistent global challenge, shaping access to resources, new technology and decision-making power especially in developing economies. Despite decades of policy efforts and international commitments, inequalities between men and women remain in areas such as education, employment, and access to energy (UNDP, 2016). In addition, women are believed to be more vulnerable to climate change because of socially determined roles that increase their dependence on natural resources such as traditional biomass and open fires which exposes them to health risks and reinforces gender inequality (Chikulo, 2014; Räty and Carlsson Kanyama, 2010). On the other hand, the global shift toward clean energy is transforming energy systems and economic structures in ways that can reduce gender inequality by empowering women, particularly through decreasing the time spent on unpaid work such as collecting firewood.

In addition, clean energy consumption supports the education and health of women and girls through electrification and clean cooking which reduces indoor pollution and provides night lighting for studying (Bera et al., 2024). The clean energy transition is increasingly viewed as a pathway to improve socio-economic outcomes, including gender equality, and is prioritized as a catalyst for reducing persistent gender inequalities, particularly in developing countries (Johnson et al., 2020). Resultantly, the issues of gender equality and sustainable energy are reflected in global and regional frameworks. The 2030 Agenda for Sustainable Development emphasizes universal access to affordable clean energy while promoting gender equality and women's empowerment under SDGs 5 and 7. At the continental level, Africa's Agenda 2063 prioritizes gender equality under Aspiration 6, aiming to achieve equality in all spheres, including energy access, by 2063. These aspirations cascade to regional level, where Southern African nations are signatories to the Southern African Development Community (SADC) Protocol on Gender and Development, adopted in 2008. However, despite all these aspirations gender and cultural norms often lead to different roles and energy needs for men and women resulting in women disproportionately bearing the burden of household energy management.

Southern Africa is well positioned to reap the gender-transformative benefits of the clean energy transition due to its substantial renewable energy potential, particularly in solar power. The region receives over 2,500 h of sunlight annually, highlighting the potential of solar power, while hydropower remains largely untapped accounting for 52% of the region's renewable electricity capacity due to high construction costs and vulnerability to climatic shocks such as droughts (IRENA, 2019), (IEA, Renewables 2020, 2020). Despite this vast renewable energy potential, according to (IEA, SDG7: Data and Projections, 2024) "about 970 million people in Africa were without clean cooking access while 600 million people of the total population lacked access to electricity mostly in Sub-Saharan Africa." This dire energy scarcity situation significantly impacts women's daily lives, increases time spent collecting traditional fuels, exposes them to health risks, limits their access to education and income-generating activities (Chikulo, 2014; Bera et al., 2024).

Therefore, the fundamental concept of the difference between men and women's energy needs and use influencing energy choices is the main basis of research on energy consumption and gender development (Bera et al., 2024; Cecelski, 2000). Existing studies established that access to modern clean energy can improve gender outcomes by reducing time poverty, enhancing health, and increasing economic participation (Ding et al., 2019; Feenstra and Clancy, 2020; Opoku et al., 2021; Li et al., 2025). More recent studies on the distributional effects of renewable energy expansion focused on income inequality and found mixed results (Topcu and Tugcu, 2020; Acheampong et al., 2021; Huynh and Phan, 2024; Kunawotor, 2025). However, some studies (Topcu and Tugcu, 2020; Kunawotor, 2025) found that clean energy reduced income inequality and emphasized the need for strong regulatory quality and government effectiveness which is relevant to this study.

Furthermore, previous research on renewable energy and gender development has mainly focused on developed countries or broad cross-country developing countries' samples due to limited gender disaggregated data (Munuswamy et al., 2011). However, broad cross-country studies often ignore important regional differences in economic structure that also influences how women benefit from technological advancements such as the clean energy shift. For instance, dependence on extractive industries, gender segmentation of labor markets may affect how the expansion of renewable energy influences gender inequalities. Given that the recurring theme from literature has been the contextual nature of the benefits from clean energy use (Johnson et al., 2020). This study provides context specific evidence on the important relationship between clean energy consumption and gender inequalities in Southern Africa.

This study uses panel data methodology and goes beyond income inequality by conceptualizing gender inequality using the UNDP's Gender Inequality Index (GII) which is a broad index covering critical areas including reproductive health, labour and empowerment (Gonzales et al., 2015). The study contributes to the limited empirical literature on the effects of renewable energy consumption on gender inequality in the Southern African context and Sustainable Development Goals 5 and 7. The study therefore provides insightful recommendations for designing gender sensitive clean energy policies required to benefit from the gender transformative opportunities presented by the energy shift to clean energy. This paper consists of five sections and section two outlines the theoretical and empirical literature that form the conceptual and theoretical framework of the study. Section three includes the detailed methodology employed in this study including data sources, definition of variables, model specification and diagnostic tests. Section 4 presents the results and policy recommendations while section 5 is the conclusion of the study.

1.1. Gender Inequality in Southern Africa

Gender inequalities in Southern Africa are driven by structural issues, labor market segmentation and institutional constraints limiting the full participation of women in economic activities and decision making (Opoku et al., 2021; IEA Africa Energy Outlook, 2022). Moreover, female-headed households in Southern Africa were often found to consume less energy than those with a male head of household irrespective of their financial situation resulting in difficulties for women (Bera et al., 2024; Räty and Carlsson Kanyama, 2010; Parikh, 1995). Table 1 presents selected gender inequality indicators for the countries under study. Table 1 shows persistent gender gaps in labor force participation, representation in parliament and income which are crucial to the clean energy shift given that rural women in Africa spend an average of 100 hours annually gathering firewood (Chikulo, 2014). Therefore, access to clean energy may influence economic opportunities and gender equality outcomes such as employment due time saving impacts for women. On the other hand, Figure 1 shows the gender inequality trends in Southern Africa as captured by the Gender Inequality Index for the period (1995-2022).

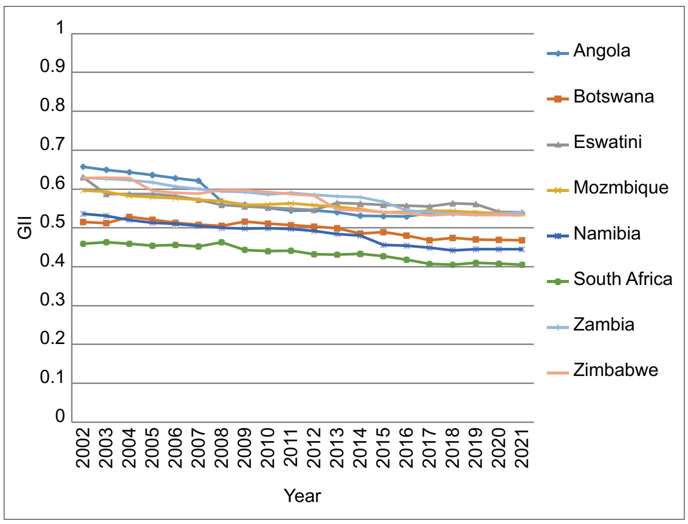
Figure 1 shows that countries such as South Africa, Namibia and Botswana exhibited lower GII values of below 0.5, while the rest of the nations including Zambia, Zimbabwe, Eswatini, Angola and Mozambique recorded higher level of gender inequality. Which points to slow progress and persistent gaps in female reproductive health, political representation and labour force participation captured by the GII. The overall regional pattern shows uneven slow progress in the improvement of gender inequalities which signifies structural barriers limiting women's full participation in socio-economic development. This is also evidenced by poor maternal health mortality which has been a major challenge in Southern Africa. Although the GII provides a comprehensive empirical measure of gender inequalities it does not explain the structural and institutional factors shaping them. Therefore, these underlying dynamics shaping gender inequalities in Southern Africa can be understood through

Table 1: Participation in labour force, parliament and income gender gap in Southern Africa (2024)

Country	Female LFPR (%)	Male LFPR (%)	Women in parliament (%)	Men in parliament (%)	Female income ($000)	Male income ($000)
Angola	73.4	77.5	39.5	60.5	4.76	7.07
Botswana	73.8	66.4	8.7	91.3	13.60	17.49
Eswatini	51.0	54.2	21.6	78.4	8.09	10.04
Mozambique	77.8	80.5	39.2	60.8	1.09	1.42
Namibia	56.4	63.1	40.6	59.4	8.83	10.76
South Africa	55.2	61.8	44.7	55.3	9.52	17.65
Zambia	67.6	66.7	15.0	85.0	2.84	3.91
Zimbabwe	62.9	74.4	28.1	71.9	2.09	2.34

Source: World Bank Development Indicators and World Economic Forum (2024). The table shows key gender inequality indicators where LFPR is Labour Force Participation and income is measured in (US$000)

Figure 1: Southern Africa gender inequality trends for the period (2002-2021)



Source: UNDP Data; 2023

theoretical perspectives on the important relationship between renewable energy consumption and gender inequalities.

2. THEORETICAL REVIEW

This study seeks to answer the important questions of how the transition toward renewable energy intersect with existing gender inequalities? Also, whether expanding access to energy resources reduces gender inequality? These questions are central to feminist political economy, which views gender inequality as structurally embedded within economic and institutional systems rather than as an outcome of individual choices (Buchanan et al., 2020; Bell et al., 2020; Sovacool et al., 2023). From this perspective gender inequality can be reproduced through socioeconomic institutions including education, health, labour markets and technological advancement such as the clean energy shift which shape the opportunities available to men and women.

Traditional development models assumed that economic development automatically reduces gender inequalities which has resulted in the persistence of gender inequalities because economic systems are influenced by social and institutional systems that shape access to opportunities (Chauhan and Vaghela, 2026). Therefore, this study draws from the energy feminist political economic theory and the capabilities approach which offer different perspectives on how renewable energy expansion is not gender neutral and affects gender outcomes. The Feminist political economic theory postulated that social, economic and institutional structures shape unequal opportunities and gender outcomes.

Furthermore, the Feminist political economic theory also emphasises the importance of unpaid care work and its implications on women's participation in economic activities. The unequal distribution of unpaid care work reinforces gender inequalities in education and labour market participation and indicates how social norms and institutional structures shape gender relations within the broader process of economic development (Agenjo-Calderón and Gálvez-Muñoz, 2019; Lokot and Bhatia, 2020). The main contribution of the Feminist political economic theory to this study is that structural constraints limit women's participation in social and economic development. Which implies that energy issues are socio-economic and can be influenced by structural gender inequalities in labour and access to resources such as land, energy and decision making.

On the other hand, the capabilities approach emphasizes how women's access to energy is limited by gender differences, which can affect their health and educational capabilities to live better lives. The approach comprehensively considers most factors needed for well-being including resources, social institutions, economic growth and the conduciveness of the decision-making conditions (Alkire, 2005). Therefore, the improvement in gender inequalities as measured by the Gender Inequality Index were interpreted as improved capabilities for women and girls due to renewable energy consumption (Sen, 1993; Nussbaum, 2000; Jain, 2020). However, the most important aspect of the capabilities approach is that it brought a different framework for conceptualizing inequality beyond examining income inequalities in isolation.

Additionally, resource-based theories often ignore the reality that people have different capacities to transform resources into capabilities due to environmental, social, or personal factors including public infrastructure, social norms, and customs and legal regulations. The capabilities approach's incorporation of nonmarket aspects of well-being makes it more comprehensive and very valuable for energy and gender inequality research because it maintains the importance of care, social interactions, and interdependence among family and communities (Fukuda-

Parr and Cid-Martinez, 2019). Although it does not cover all capabilities for women, the capabilities approach has provided a widely acceptable way to measure gender inequality.

Access to modern clean energy impacts on several capabilities of women including health capabilities that can be attained through access to clean cooking fuels which reduces indoor pollution (Li and Zhou, 2023). While economic capabilities can be improved through the time saved by clean energy use which allows for their participation in economic activities (Kolovich et al., 2024). Educational capabilities of women can also be enhanced by the time saved and extra lighting to study during the night. Most importantly, the capabilities approach does not just assume that improvements in aggregate infrastructure such as renewable energy expansion automatically translates into the improvement of women's capabilities but also depends on institutions, labour market structure and household power dynamics (Türkoğlu and Kardoğan, 2018). Which implies that renewable energy expansion alone can fail to improve women's capabilities in the absence of gender sensitive inclusive policies.

Furthermore, the Multi-level Perspective (MLP) theory was used to explain the pathways through which the clean energy transition influences social structures and gender inequalities. It comprises of landscape (macro), regime (meso), and niche (micro) levels (Gbolonyo et al., 2025). The landscape, or macro level, represents the broader context that evolves slowly over time, exemplified by the global shift toward clean energy. The regime level refers to the dominant socio-technical system, in this case, the continued consumption of fossil fuels or polluting energy sources. Finally, the niche level encompasses grassroots initiatives where clean energy projects and technologies are developed and implemented. These levels also illustrate that the energy transition is a multi-layered and gradual process which may take time to produce visible results although there is momentum at the global level for a just and equitable shift toward renewable energy. Nonetheless, this study focuses on the macro level where policies can be utilised to break down the dominant regime of fossil fuel-based energy consumption in Southern Africa. Which implies that macroeconomic policies such as trade management and aid coordination policies may also impact gender inequalities.

2.1. Empirical Review

Despite strong theoretical arguments linking gender inequality to structural and institutional factors, empirical evidence gives mixed results on the extent to which renewable energy use influences gender inequality. Existing studies have examined the effects of economic growth, energy consumption, income distribution and institutional quality on gender outcomes; however, their findings varied across contexts and methodologies. Gender inequality and renewable energy consumption have been conceptually linked across different dimensions including household dynamics, labour markets, social norms and broader development outcomes such as health, education, and economic opportunities. The household dynamics studies (Bera et al., 2024; Li and Zhou, 2023; Longe, 2021; Mohideen, 2012; Lépine and Strobl, 2013) focused on decision-making, division of labour, control over resources, and time-saving effects, highlighting how gender roles shape energy use and the distribution of welfare outcomes. Which implies that increases in renewable energy consumption may not automatically translate into inclusive socioeconomic development outcomes.

In addition, past studies on the role of renewable energy consumption in shaping the social norms found that access to clean energy enhanced the bargaining power of women while challenging the traditional gender norms especially in urban areas and educated households (Feenstra and Clancy, 2020; Barnes et al., 2011; Ngarava et al., 2022). Furthermore, women's greater bargaining power in the home resulted in several positive outcomes in line with Sen's Capabilities approach (Sen, 1993), including improved marital life, household income, health and education of children, human capital and labor supply of women. Therefore, these studies established that renewable energy access could break down gender norms when provided socially and economically through gender sensitive renewable energy policy initiatives.

Furthermore, (Koengkan and Fuinhas, 2021) illustrated the connection between structural gender inequality and decision-making power and highlighted that gender inequality limits women's influence over clean energy use, environmental decisions and increases CO_2 emissions. However, evidence on whether renewable energy improves women's agency and decisionmaking remains limited and heterogeneous (Cellini et al., 2025). In some contexts, increased electricity access did not result in equitable household decisionmaking due to persistent intrahousehold power imbalances and gender norms (Rosenberg et al., 2019; Winther et al., 2020). These findings suggest that renewable energy expansion may be contextual and insufficient in some cases to transform gendered decisionmaking dynamics without gender sensitive policies. Although these initial studies provided compelling evidence regarding the relationship between gender inequality and clean energy transitions, they overlooked the comprehensive policy-level perspective on gender and renewable energy.

Resultantly, emerging research on the gender transformative impacts of the energy shift to modern clean energy has progressively moved to include broader economic factors affecting women such as income inequality, labour market dynamics and renewable energy supply chains(Cecelski,, 2000), (Pearl-Martinez and Stephens, 2017). Higher levels of income inequality were associated with women's limited access to resources and renewable energy consumption (Acheampong et al., 2021; Uzar, 2020). Whilst some studies focused on the employment and livelihood benefits from modern clean energy supply chains and found that women's empowerment and confidence increased when they actively participated in the supply chains (Adair-Rohani et al., 2013; Bluedorn et al., 2023; Boudreaux and Nikolaev, 2019; Arias et al., 2022). Which demonstrates that energy security is essential for women to utilize employment opportunities from the shift to renewable energy. However, in as much as these studies alluded that the shift to modern clean energy had opportunities for gender equality, they all emphasized the persistence of significant challenges for women to fully benefit from these opportunities especially in developing nations (Pearl-Martinez and Stephens, 2017).

According to (Dumga and Goswami, 2024), improved economic empowerment, which may be represented by GDPpc increases adoption of clean energy sources such as solar and biogas. On the other hand, (Bera et al., 2024; Gbolonyo et al., 2025) found that clean energy use also improved the empowerment of women. In contrast to the prevailing views, (Doan et al., 2024) found that improved womens' political empowerment did not improve clean energy consumption although it enhanced shifts to other sources of clean energy such as wind and geothermal energy. Which highlights that the effect of women empowerment on clean energy consumption may be contextual. Resultantly, more recent studies highlighted the importance of stronger regulatory and institutional quality because it is often associated with lower gender inequalities and greater access to modern clean energy (Huynh and Phan, 2024; Kunawotor, 2025; Boudreaux and Nikolaev, 2019). Strong regulatory quality supports the implementation of gender sensitive policies and improves women's access to opportunities and resources. Therefore, improved regulatory and institutional quality were also found to improve transparency and accountability which enhances women's participation in politics (Rodríguez-Pose and Ketterer, 2020).

It is evident that prior research thoroughly established that women could benefit from access to modern clean affordable energy. However, empirical evidence showed that there are some paradoxes that challenge the capabilities approach and feminist political economy theories in practice because gender norms and intra-household power dynamics determine energy consumption decisions and the distribution of the benefits especially in developing nations (Bouzarovski and Petrova, 2015). Which highlights that gender equality is impacted by cultural, societal and intra-household dynamics which may hinder nations from benefitting from the gender transformative impacts of the clean energy shift.

Furthermore, most past studies ignored the structural opportunities and challenges for advancing gender equality and sustainable energy transitions (Cecelski, 2000). Which signifies that although the broader link between renewable energy access and its benefits for gender outcomes has been extensively studied, empirical evidence shows inconclusive results. Which indicates a gap in understanding how renewable energy contributes to reducing gender inequality. Additionally, the interaction between renewable energy and gender inequality as measured by a broader measure capturing structural inequalities such as the Gender Inequality Index employed in this study specifically remains understudied in the Southern African context given that gender norms vary across regions. Therefore, this study adds to empirical literature on the gender transformative impacts of the clean energy shift and provides useful insights on the necessary policies that can support Southern African countries to benefit from the gender transformative impacts of the energy shift.

3. METHODOLOGY

The study utilized robust panel regression analysis to examine the extent of the important relationship between renewable energy consumption and gender inequality. To examine this relationship the baseline model was estimated based on extensive literature (Kunawotor, 2025; Benbitour et al., 2023; Nguyen and Su, 2021). Gender inequality was proxied by the Gender Inequality Index (GII) in line with studies such as (Benbitour et al., 2023) while regulatory quality captures institutional conditions (Kunawotor, 2025). Macroeconomic controls, including GDP per capita, official development assistance (ODA) per capita, foreign direct investment (FDI), and trade openness, were included to account for other economic factors influencing gender inequality (Nguyen and Su, 2021). The study covers the period 2002-2021, capturing both international initiatives, including the Beijing Declaration (1995), Kyoto Protocol (1997), the 2015 Sustainable Development Agenda, and national efforts to promote gender equality in energy access. The Southern African region has implemented regional strategies to advance gender equality, making it particularly relevant for examining the relationship between clean energy use and progress toward SDG 5 and SDG 7. Based on this context and the theoretical framework, the study hypothesizes that renewable energy consumption influences gender inequality in Southern Africa.

3.1. Data Sources and Variable Measurement

Annual data for the period (2002-2021) were compiled from credible publicly available sources shown in Table 2. The sample consists of eight developing countries as shown in appendix table 1 Angola, Botswana, Eswatini, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe selected based on data availability, persistent gender inequalities, and energy access challenges, coupled with varying levels of renewable energy consumption and institutional quality. It is important to note that several indices are available internationally to measure gender inequalities. These include the Women's Economic Opportunity Index (WEOI), Social Institutions and Gender Index (SIGI), Country Policy and Institutional Assessment Gender Equality Rating (CPIA), IMF GII, and the Global Gender Gap Index (Gonzales et al., 2015; Gaye et al., 2013). However, these alternative gender inequality indices have limitations such as shorter historical coverage or missing country data. Therefore, the GII (and GDI) were preferred because of data availability across (2002-2021), and cross-country comparability. However, GII was developed because of many improvements to the GDI to capture structural inequalities across health, labor, and empowerment outcomes rather than focusing solely on income disparities in-line with the capabilities approach (Gonzales et al., 2015). Nonetheless, the effects of clean energy use on the two indices were analysed and compared.

Given that the focus of the study is on modern clean energy consumption, the independent variable (Renewable Energy Consumption) collected from the World Bank was utilised as used in studies such as (Ponce, 2020). Renewable energy consumption was expected to have a positive impact on gender inequality in Southern Africa as it is believed to free up more time for women. On the other hand, access to electricity data collected from the World Bank was also included as an independent variable because energy systems should be fair even beyond mere distribution up to participation and decision making (Li and Zhou, 2023). Hence, access to electricity is expected to reduce gender inequalities.

Table 2: Description of variables

Variable	Proxy of variable	Source
Gender Inequality Index (GII)	Composite index computed using dimensions of reproductive health, empowerment and labor market gender disparities.	UNDP
Gender Development Index (GDI)	Composite index covering three human development dimensions namely, health, education and economic resource	UNDP
Renewable Energy Consumption (REN)	Percentage of renewable energy in overall final energy consumption	WDI
Access to Electricity (AE)	The percentage of the population with access	WDI
Gross Domestic Product per capita (GDPpc)	GDP per capita (current US$)	WDI
Official Development Aid per capita (ODA)	Net ODA received per capita (current US$)	WDI
Trade Openness (TO)	Sum of imports and exports as a proportion of GDP	WDI
Foreign Direct Investment (FDI)	Net FDI flows as a percentage of GDP	WDI
Regulatory Quality (RE)	Perceptions of the government's capacity to create conducive laws and rules that allow and encourage the growth of the private sector	WDI
Government Effectiveness (GE)	Perceptions of the quality of policies and services provided by the government and independence from political influence	WDI
Rule of Law	Perceptions of the confidence which agents have in the law and abide by it and the rules of society particularly contract enforcements and respect for property rights.	WDI

This table shows the definition of variables and data sources include the World Bank Development Indicators (WDI) and the United Nations Development Programme (UNDP)

The Feminist Political Economy theory emphasises that gendered labour markets and gender norms determine whether women can equally benefit from trade and development assistance(OECD, 2023) (Zarrilli and Linoci, 2020). Therefore, Trade openness and Official Development Assistance were expected to reduce gender inequalities. Furthermore, governance parameters including political power, government effectiveness, rule of law and quality of institutional frameworks have been found to play a critical role in creating gender sensitive policies (Uzar, 2020). Therefore, Regulatory Quality, Government Effectiveness and Rule of law were expected to have a positive effect on gender inequality since they promote social justice.

Also, Foreign Direct Investment was included in the model given that it influences gender inequalities through FDI inflows into projects that prioritise gender equality (Ergun et al., 2019). FDI was expected to reduce gender inequalities. Lastly, GDP per capita has been used in many past studies as an effective composite and comparable measure of economic development as it indicates the economic progress of a nation. It impacts gender inequalities primarily through labour productivity and the efficiency of allocation of resources (Ram et al., 2024). Therefore, GDPpc was expected to reduce gender inequalities in Southern Africa. The log transformations were applied to address skewness and outliers (Benoit, 2011). Which implies that the analysis of the log transformed variables was based on proportional changes and not absolute differences making it easier to interpret for policymaking.

3.2. Descriptive Statistics

The preliminary analysis of distributional properties of the data set showed that the average renewable energy consumption for the selected Southern African countries was 55.95% which was quite reasonable enough to be impactful on gender inequality as shown in Table 3. On the other hand, the average gender inequality was 0.535 which is quite high because gender equality is attained at zero, indicating that the countries still have a long way to go to attain gender equality. Another important energy indicator, access to electricity had an average of 44.6% which is below half also signifying the serious energy challenges in Southern Africa where some people still do not have access to electricity.

Economic performance also varied significantly amongst countries and South Africa being the biggest economy had the highest level of GDP per capita of US$8 737.08 while Mozambique had the lowest (US$303.66). However, despite the huge variance in GDP per capita, country descriptive statistics (Appendix Table 3) show that gender inequalities did not vary as much signifying that economic growth may not be inclusive in Southern Africa. GII values ranged from 0.44 in South Africa to 0.58 in Zambia. Gender inequalities were comparatively lower in high income countries such as South Africa, Botswana and Namibia. Whilst Renewable energy consumption (REN) was particularly high in countries such as Zambia, Mozambique, and Zimbabwe which historically relied on hydropower to generate electricity.

However, significantly lower levels of renewable energy consumption were observed in South Africa and Botswana, reflecting differences in energy structures and South Africa's coal energy reliance (Osabohien et al., 2025). Access to electricity (AE) also varied considerably amongst countries with near-universal access in South Africa compared to much lower levels in Mozambique and Zambia. Which could be attributable to low rural electrification and continued use of traditional polluting fuel for cooking especially in Mozambique (Anenberg, 2017). In terms of economic indicators, GDP per capita is highest in South Africa and Botswana but remained low in countries such as Mozambique and Zimbabwe. Additionally, there is substantial variation in external financial flows, with Mozambique recording notably high FDI inflows, while ODA per capita was relatively higher in countries such as Namibia and Eswatini and lowest in Angola. Overall, these differences highlight the heterogeneity in both structural conditions and energy profiles across the region.

Correlation amongst the variables which shows the level of a relationship amongst variables was presented statistically by a correlation matrix presented in appendix table 2. The independent variables with the strongest correlations with the dependent variable (GII) included the positive correlation between Renewable Energy consumption (REN) and Gender inequality (GII), signifying that clean energy consumption had a strong relationship with gender inequalities in Southern Africa. Access to

Table 3: Descriptive statistics

Variable	Obs	Mean	Standard deviation	Min	Max
GII	152	0.535	0.058	0.405	0.657
REN	152	55.953	27.806	7.72	93.67
AE	152	44.558	20.283	8.1	90
FDI	152	4.168	6.962	−10.725	39.456
GDPpc	152	3207.901	2286.584	303.665	8737.08
ODA	152	4.898	6.823	0.034	43.702
TO	152	83.085	23.981	45.644	175.798
RQ	152	39.044	22.945	0.98	75.962

This table shows the descriptive statistics including the mean, Standard Deviation, Minimum and Maximum values of the data

Electricity (AE), Regulatory Quality (RE) and GDPpc also had a strong negative correlation with Gender Inequality as anticipated. On the other hand, Multicollinearity entails the presence of high correlation between independent variables in a regression model (Daoud, 2017). If independent variables are highly correlated estimation of their unique impact on the dependent variable becomes biased. Therefore, the Variance Inflation Factor (VIF) was used to ensure the model was statistically sound and reliable. The results showed the absence of multicollinearity amongst the independent variables used in this study given that VIFs ranging from 1 to 5, indicating the absence of multicollinearity (VIF results in the Appendix Table 4).

3.3. Model Estimation Techniques

Robust panel data regression analysis was the most appropriate method because it allows for country variations over time by tracking changes within countries or differences between the countries using averages compiled across countries or individuals over time (Torres-Reyna, 2007). The fixed effects technique calculates changes according to variation in the country's average within a study period allowing the model to focus on within country variation. This controls for variables that are difficult to detect or quantify, such as cultural norms or national policies, federal legislation and international agreements (Baltagi, 2005). Whilst on the other hand the random effects models account for differences across countries assuming that they are uncorrelated with the regressors. Additionally, panel data analysis allows for the inclusion and control of unobserved time effects which may result from global shocks affecting all the nations during the study period. These may include international economic changes affecting the adoption of clean modern energy and gender inequalities.

This reduces omission variable bias and improves the estimation because the time invariant factors and global shocks are controlled for making it possible to examine how changes in the independent variable influence gender inequalities over time (Torres-Reyna, 2007). However, to ascertain which panel data model would be more consistent with the data, the Hausman test was performed prior to estimating the panel regression models and the results are shown in appendix table 5. To estimate the panel data models employed in this study, equation (1) shows the baseline fixed effects model to examine the relationship between renewable energy consumption and gender inequality, with Gender Inequality Index (the dependent variable), independent variables and year fixed effects (Model 1).

$$GII_t = \beta_0 + \beta_1 REN + \beta_2 lnODApc + \beta_3 lnGDPpc + \beta_4 TO + \beta_5 AE + \beta_6 RQ + \beta_7 FDI + \lambda_t + \mu_{it} \quad (1)$$

To mitigate contemporaneous endogeneity concerns and address potential simultaneity concerns, Model 2 introduces a one-year lag of renewable energy consumption, which helps mitigate reverse causality while retaining the within-country variation captured by fixed effects as shown in equation (2).

$$GII_t = \beta_0 + \beta_1 REN_{t-1} + \beta_2 lnODApc + \beta_3 lnGDPpc + \beta_4 TO + \beta_5 AE + \beta_6 RE + \beta_7 FDI + \lambda_t + \mu_{it} \quad (2)$$

The non-linear quadratic form of renewable energy was included in Model 3 using the random effects model to test for potential non-linear effects of renewable energy on gender inequality at different levels of consumption as shown in equation (3).

$$GII_t = \beta_0 + \beta_1 REN^2 + \beta_2 REN + \beta_3 lnGDPpc + \beta_4 TO + \beta_5 AE + \beta_6 RE + \beta_7 FDI + \beta_8 lnODApc + \mu_{it} + \lambda_t + \mu_{it} \quad (3)$$

3.4. Diagnostic Tests

Diagnostic tests were performed to validate the models and show that the selected model estimation techniques were appropriate and unbiased. These tests included heteroskedasticity, serial autocorrelation and cross-sectional dependency tests. Firstly, the data was tested for cross-sectional dependency, which can be caused by common shocks, spatial dependence, and unobserved components (Torres-Reyna, 2007).

Cross-sectional dependency was highly anticipated to exist because these nations are in the same region and share many cultural and economic traits. Accordingly, the Friedman, Pesaran, and Frees tests produced the same results that there was cross-sectional dependency in the data set as shown in Table 4. Secondly, the reliability of panel data models is founded on the assumptions that the error terms' variance in a given model is evenly distributed and that the error terms are not correlated (Huitema and Laraway, 2006; Wallentin and Ågren, 2002). Therefore, the model (Model 1) was tested for heteroskedasticity, and autocorrelation. The results exhibited the presence of heteroskedasticity, and autocorrelation as shown in Table 5.

Thus, robust estimation techniques were applied to resolve the issues of autocorrelation, heteroskedasticity, and cross-sectional dependency in the data using the Driscoll Kraay (1998) standard errors (Beylik et al., 2022), (Hoechle, 2007). The Driscoll Kraay covariance matrix estimator was proven to be dependable and able resolve issues of heteroskedasticity, cross-sectional dependency, and autocorrelation, as applied by (Newey and West, 1987), (Andrews, 1991). However, robustness checks using random

Table 4: Tests for cross-sectional dependence

Test	Test statistic	Critical value
Friedman	44.593	0.0000***
Frees	1.208	0.1695
Pesarans CD	3.972	0.0001***

***P<0.01, **P<0.05, *P<0.1. This table shows the results of the Friedman, Frees and Pesaran CD tests

Table 5: Heteroskedasticity and autocorrelation test results

Test	Test statistic	P-value	Conclusion
Heteroskedasticity	367.70	0.0000	Heteroskedasticity present
Autocorrelation	0.6239 (Durbin Watson) 0.7931 (Baltagi–Wu LBI)	0.2680	Autocorrelation present (Tests statistic <2)

This table shows the test results for the group wise Heteroskedasticity test using the modified Wald test and the Baltagi-Wu's LBI test for autocorrelation

Table 6: Results

Variables	Model (1)	Model (2)	Model (3)
	GII	GII	GII
REN	0.00156** (0.000559)		0.00160*** (0.000356)
REN_{t-1}		0.00127** (0.000380)	
REN^2			−2.08e-05*** (7.52e-06)
FDI	0.000197 (0.000210)	0.000222 (0.000190)	−6.36e-05 (0.000455)
TO	0.000312*** (8.15e-05)	0.000241** (8.19e-05)	0.000210 (0.000156)
RQ	0.000414** (0.000164)	−3.15e-05 (0.000207)	−0.000285 (0.000287)
lnGDPpc	−0.0366*** (0.00971)	−0.0179*** (0.00485)	0.000372 (0.00968)
lnODApc	0.00942*** (0.00169)	0.00802*** (0.00173)	−0.00490 (0.00384)
AE	0.000106 (0.000162)	0.000688*** (0.000144)	0.000429* (0.000232)
Constant	0.646*** (0.111)	0.503*** (0.0514)	0.496*** (0.0772)
Observations	160	152	160
Number of groups	8	8	8
Within R^2	0.83	0.88	0.81
Overall R^2	Included	Included	0.93
Country Effects	Included	Included	Included
Year Effects			Included

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. This table shows the regression results where REN is renewable energy consumption; REN_{t-1} is the lagged variable of renewable energy consumption; REN^2 is the quadratic expression of renewable energy consumption AE is Access to electricity; TO is Trade openness; RE is Regulatory Quality; GDPpc is Gross Domestic Product per capita; ODA is Official Development assistance and FDI is Foreign Direct Investment

effects model with Rodgers (1993) cluster standard errors produced consistent results because the small number countries may limit asymptotic reliability of Driscoll Kraay standard errors. Therefore, the cluster standard errors complement Driscoll Kraay standard errors by accounting for Heteroskedasticity and within-country correlation, while Driscoll Kraay standard errors address cross-sectional dependence.

4. RESULTS

Robust panel data models were estimated in Stata 2018 using the Driscoll Kraay standard errors to estimate the relationship between renewable energy consumption and gender inequality in Southern Africa and the results are shown in Table 6. The results of the baseline model (1) indicates that a 1% increase in Renewable Energy Consumption (REN) increased Gender Inequality (GII) by 0.002 in the selected Southern African nations. Whilst at 10% increase in renewable energy consumption GII increased by 0.02 which is noticeable especially in countries faced with persistent gender inequalities. The results provide a reference to the relationship between renewable energy consumption and gender inequality for subsequent extensions to the baseline model.

The results of the lagged renewable energy consumption variable included in Model 2 to account for potential delayed effects show that the coefficient is also positive and significant, nearly identical to the relationship found in the baseline model. These results indicate that renewable energy was consistently associated with worsening gender equality, and the positive relationship is robust across alternative specifications, including fixed and random effects models. Furthermore, the results of the quadratic model capture the marginal effects and provide a deeper understanding of the effects of renewable energy consumption on gender inequality. The results show that renewable energy consumption remains significant and positive while the squared term is negative, indicating the U shape and marginal diminishing effect whose direction will change after a certain threshold (Appendix Table 6). Although the marginal effects of renewable energy on gender inequality are small because of the GII's 0-1 scale, they are meaningful for policy direction and reflect the expected diminishing impact captured by Model 3.

Overall, these results imply that these countries are off-track in terms of utilizing the gender transformative opportunities of the transition to modern clean energy in-line with past studies (Parikh, 1995; Ding et al., 2019). Which may be attributable to how clean energy projects are capital-intensive meaning that they require huge investments and create less employment opportunities for women given that technical sectors such as the clean energy sector are dominated by man in Southern Africa (Siwela and Shumba, 2026). However, this could also be due to the complexity of gender inequality as a social issue that takes time to eradicate because of structural issues and effects from other multifaceted factors including gender norms and legislation (Mohideen, 2012).

On the other hand, per capita GDP was anticipated to have a favorable effect on gender inequality through increased opportunities for women, access to education, health services and employment (Ram et al., 2024). As anticipated, the results showed that gender inequality and GDPpc were negatively related, and increased GDP per capita decreased gender inequality. On the contrary, ODA increased gender inequality, in line with the findings of (Pickbourn and Ndikumana, 2016; Bali Swain et al.,

2020) which highlighted that ODA may worsen structural gender inequalities such as those prevailing in Southern African countries. Which implies that the ODA implemented in these nations do not necessarily prioritise or target gender development. However, aggregate ODA measures may mask the effects of ODA on GII in the absence of gender disaggregated sectorial data.

Similarly trade openness worsened gender inequality in-line with the findings of (Kimura, 2016; Kuete and Voufo, 2016) because trade openness may have negative effects on gender equality if not accompanied by gender sensitive policies. These findings may reflect the sectoral composition of exports where growth is concentrated in male-dominated industries such as manufacturing or extractive sectors. Which implies that women may experience fewer opportunities and limited gains in-line with feminist political economy perspectives that emphasize that structural inequalities in labor markets shape the distributional effects of trade liberalization (Lazoroska et al., 2024). Additionally, (Terra et al., 2009) found that trade openness improved gender inequalities in highly skilled employment and not for low skilled workers where most women in developing nations are often categorized.

Furthermore, gender inequality and regulatory quality (RQ) had a positive relationship, indicating that gender inequality increased as regulatory quality improved. These results are in line with empirical findings that the impact of governance on gender outcomes varies according to context and the indicators used (Costantiello and Leogrande, 2024; Hernández-Lara et al., 2025). In line with this notion (Kurum, 2025) finds that other governance dimensions such as government effectiveness and control of corruption worsened gender inequality, highlighting the heterogeneous impacts of institutional quality on gender inequality. These findings motivated the inclusion of the interaction of renewable energy consumption with institutional dimensions, namely, rule of law and government effectiveness across the full sample. However, Government effectiveness and Rule of Law were insignificant implying that the enhancement of government institutions in the nations under study may not be targeting the reduction of gender inequalities (Appendix Table 7 for full results). Nonetheless, this may also reflect that regulatory reforms or improvements in institutional quality could coincide with structural adjustment periods or other macroeconomic changes that temporarily exacerbate gender inequalities (Nam et al., 2024).

Lastly, the baseline results of the Model conceptualizing gender inequalities using the UNDP's Gender Development index (GDI) (Model 4) employing the random effects model based on the Hausman test results show that renewable energy has an insignificant effect on gender inequalities (Appendix Table 8 for full results). This could be attributable to the more comprehensive nature of the GII to include labor, health and political representation which would be more sensitive to the independent variables used in this analysis through improved health and time saving brought by the clean energy sources compared to the GDI (Gaye et al., 2013; Gonzales et al., 2015).

5. CONCLUSION, POLICY RECOMMENDATIONS AND LIMITATIONS

The study analysed the dynamics of the relationship between clean energy use and gender inequality in Southern Africa. The results showed that in as much as it has been widely acknowledged that renewable energy consumption has the potential to reduce gender inequalities through time saving for productive activities, improved health, education, employment and entrepreneurship for women, it can also reinforce preexisting gender inequalities in the absence of gender sensitive policies. The results of this study indicated that the switch to renewable energy consumption exacerbated already existing gender inequalities in Southern Africa showing that the nations were not progressing toward a fair transition to renewable energy (Clancy et al., 2012). Which indicates that the gender transformative impacts of the shift to clean energy will not be realized automatically without holistic gender sensitive supportive policies.

These results draw attention to a significant and often disregarded possibility for the energy shift to worsen gender inequality in some contexts. Which demonstrates that the benefits of the energy shift will vary amongst regions and require significant policy shifts in contexts where social, cultural, or institutional hurdles preventing women from utilizing the opportunities still exist such as the Southern African region. Therefore, in light of these findings there is urgent need for gender sensitive renewable energy policies supported by strong regulatory and institutional frameworks in the Southern African region to provide fair access to clean energy which in turn enhances women's socioeconomic wellbeing. The economy wide gender transformative effects of clean energy while mitigating the negative impacts of climate change make it very critical for policy makers in Southern Africa to adopt gender sensitive policies and mechanisms and reverse the perpetuation of existing gender inequalities

This study clarified that gender neutral energy technological advancements alone without the necessary policies ensuring gender equality are unsustainable and socially unjust. The main recommendations to change this gender inequality perpetuating trajectory of clean energy use in Southern Africa include that renewable energy expansion initiatives should be carefully designed to promote women's participation in energy-related sectors and decision-making processes. These supportive initiatives to ensure that women equally benefit from the clean energy shift can be implemented by targeting and incentivizing the participation of women in clean energy projects and initiatives. On the other hand, access to electricity was insignificant which highlights access to electricity needs to go beyond just providing electricity (Southern African Development Community, 2018). For instance, the ongoing rural electrification programs need to be gender sensitive and complemented by targeted social programs that empower women (Nguyen and Su, 2021).

On the other hand, the results showed that the interaction of renewable energy with GDPpc enhanced the gender transformative effects of clean energy consumption. Which highlights the importance of promoting inclusive economic growth policies that support women's well-being (Ram et al., 2024). Contrary to expectations, regulatory quality was associated with higher gender inequality which indicates the need for governance reforms that explicitly incorporate gender-inclusive mechanisms. Which implies that Governance reforms should integrate gender-focused mechanisms to translate into more equitable outcomes for women (Kunawotor, 2025). These mechanisms include carrying out policy assessments and designing policy initiatives that ensure women are not disadvantaged such as encouraging female participation in decision-making and clean energy oversight bodies.

Similarly, Official Development Assistance and trade openness were found to increase gender inequality. Which indicates the need for restructuring aid programs and trade policies to target gender inequalities effectively, for example by supporting women's empowerment and inclusive development initiatives (Pickbourn and Ndikumana, 2016). Also supporting women's trade enterprises and trade-related job opportunities would help ensure that trade openness contributes to the reduction of gender inequality rather than assuming that it evenly benefits every group (Kuete and Voufo, 2016). These findings emphasize the importance of gender disaggregated sectoral data, integrated energy, economic, institutional, trade, and aid policies that clearly embed gender-focused strategies. This shows that a holistic gender sensitive policy approach is required for the Southern African nations to benefit from the gender transformative effects of clean energy use. Policymakers should urgently move beyond general initiatives and design clean energy programs with clear built-in mechanisms that actively empower women, monitor outcomes to ensure that the region benefits from the gender transformative effects of the clean energy shift.

Although the gender transformative impacts of clean energy use are very critical for the Southern African region and this study proffers policy recommendations for the reduction of gender inequalities through the transition to modern clean energy it also had limitations. The lack of gender disaggregated data for important aspects of women's well-being including renewable energy data limited the results of this study. Moreover, the data was very scarce for the developing countries which face serious gender inequalities. As a result, the study relied on country level data from a limited sample and may not generalize broadly or reflect causal effects at the household level. Therefore, the results did not capture the intra-household dynamics which also play a critical role in gender development and caution is needed when extrapolating macro-level results to micro-level gender dynamics. Despite the GDI and GII are widely used gender inequality indicators, they do not capture all aspects of gender inequalities particularly those unique to developing nations. However, the GII is still capable of pointing to the areas requiring urgent policy attention. The limitations of this study underscore the areas for future studies on this important relationship between clean energy use and gender inequalities to include household dynamics and renewable energy gender disaggregated data in aggregate models on the intersectionality of gender and clean energy consumption.

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APPENDICES

Appendix Table 1: List of countries

Angola
Botswana
Eswatini
Mozambique
Namibia
South Africa
Zambia
Zimbabwe

Appendix Table 2: Matrix of correlations

Variables	GII	REN	AE	FDI	TO	RQ	lnGDPp	lnODAp
GII	1.000							
REN	0.839*	1.000						
	(0.000)							
AE	−0.759*	−0.749*	1.000					
	(0.000)	(0.000)						
FDI	0.138	0.263*	−0.370*	1.000				
	(0.082)	(0.001)	(0.000)					
TO	0.260*	0.052	−0.271*	0.233*	1.000			
	(0.001)	(0.517)	(0.001)	(0.003)				
RQ	−0.694*	−0.766*	0.514*	−0.035	0.084	1.000		
	(0.000)	(0.000)	(0.000)	(0.664)	(0.292)			
lnGDPpc	−0.711*	−0.837*	0.741*	−0.410*	0.048	0.686*	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.548)	(0.000)		
lnODApc	0.143	0.321*	−0.245*	0.376*	0.193*	0.088	−0.195*	1.000
	(0.071)	(0.000)	(0.002)	(0.000)	(0.015)	(0.267)	(0.013)	

***P<0.01, **P<0.05, *P<0.1. This table shows the correlation matrix for all the variables used in the study

Appendix Table 3: Country descriptive statistics (Mean values)

Country	GII	REN (%)	RQ (%)	AE (%)	GDP per capita	ODA per capita	Trade (%)	FDI (%)
Angola	0.57	56.0	16.1	37.1	2817.4	13.5	86.8	0.3
Botswana	0.50	28.8	71.7	53.0	5803.8	58.4	96.0	2.6
Eswatini	0.57	68.7	39.2	53.3	3417.2	73.4	105.9	1.5
Mozambique	0.56	85.2	30.1	19.9	501.6	75.0	86.5	16.8
Namibia	0.49	32.1	56.7	46.0	4586.0	91.0	94.7	4.6
South Africa	0.44	9.4	63.7	83.5	6402.4	18.5	54.0	1.7
Zambia	0.58	86.0	30.8	29.7	1208.5	72.5	70.7	5.0
Zimbabwe	0.57	80.5	3.2	40.2	1046.0	46.5	68.1	1.3

GII: Gender inequality index, REN: Renewable energy, RQ: Regulatory quality, AE: Access to electricity, GDP: GDP per capita (constant US$), ODA: Official development assistance per capita, Trade: Trade openness, FDI: Foreign direct investment

Appendix Table 4: Multicollinearity test results

Model	VIF	Conclusion
Model 1	3.42	No Multicollinearity (mean Vif <10)
Model 3	3.83	No Multicollinearity (mean Vif <10)
Model 4	3.42	No Multicollinearity (mean Vif <10)
Model 5	3.81	No Multicollinearity (mean Vif<10)
Model 6	4.07	No Multicollinearity (mean Vif <10)
Model 7	4.39	No Multicollinearity (mean Vif <10)

Appendix Table 5: Hausman test results

Model	Test statistic	P-value	Conclusion
Model 1	14.05	0.050	Fixed Effects Model/Random effects efficient
Model 2	17.26	0.015	Fixed Effects Model was more efficient
Model 3	15.06	0.06	Random Effects Model was more efficient
Model 4	13.85	0.053	Random Effects/Fixed Effects Model efficient
Model 5	15.38	0.052	Fixed Effects Model was more efficient
Model 6	15.62	0.048	Fixed Effects Model was more efficient
Model 7	15.84	0.045	Fixed Effects Model was more efficient

Appendix Table 6: Renewable energy consumption marginal effects table

REN_at	dy/dx	Standard	Error	z	P>z	[95% CI]
1	0.0018472	0.001	3.340	0.001	0.001	0.003
2	0.0017857	0.001	3.570	0.000	0.001	0.003
3	0.0017241	0.000	3.840	0.000	0.001	0.003
4	0.0016626	0.000	4.160	0.000	0.001	0.002
5	0.0016011	0.000	4.560	0.000	0.001	0.002
6	0.0015396	0.000	5.030	0.000	0.001	0.002
7	0.0014781	0.000	5.580	0.000	0.001	0.002
8	0.0014165	0.000	6.130	0.000	0.001	0.002
9	0.001355	0.000	6.550	0.000	0.001	0.002
10	0.0012935	0.000	6.580	0.000	0.001	0.002
11	0.001232	0.000	6.090	0.000	0.001	0.002
12	0.0011704	0.000	5.250	0.000	0.001	0.002
13	0.0011089	0.000	4.360	0.000	0.001	0.002
14	0.0010474	0.000	3.570	0.000	0.000	0.002
15	0.0009859	0.000	2.920	0.003	0.000	0.002
16	0.0009244	0.000	2.400	0.016	0.000	0.002
17	0.0008628	0.000	1.990	0.047	0.000	0.002
18	0.0008013	0.000	1.650	0.099	−0.000	0.002
19	0.0007398	0.001	1.380	0.169	−0.000	0.002
20	0.0006783	0.001	1.150	0.251	−0.000	0.002

Appendix Table 7: Results for models with governance indicators

Variables	Model (5) (Regulatory Quality)	Model (6) (Rule of Law)	Model (7) (Government Effectiveness)
	GII	GII	GII
REN	0.00125**	0.00117*	0.00142**
	(0.000429)	(0.000497)	(0.000433)
AE	0.000955***	0.000887***	0.00103***
	(0.000130)	(0.000101)	(0.000133)
FDI	0.000291	0.000297	0.000314
	(0.000166)	(0.000184)	(0.000189)
TO	0.000265**	0.000254**	0.000264*
	(8.72e-05)	(0.000105)	(0.000113)
RQ	−0.000292		
	(0.000197)		
lnODApc	0.00516**	0.00573***	0.00532**
	(0.00167)	(0.00131)	(0.00153)
lnGDPpc	−0.0162**	−0.0164**	−0.0165*
	(0.00603)	(0.00650)	(0.00707)
REN_RQ	−1.11e-06		
	(4.12e-06)		
Rulelaw		3.63e-05	
		(0.000216)	
REN_RL		−7.16e-06	
		(9.21e-06)	
GE			−0.000397
			(0.000252)
REN_GE			1.05e-05
			(8.37e-06)
Constant	0.557***	0.549***	0.556***
	(0.0605)	(0.0603)	(0.0608)
Observations	160	160	160
Number of groups	8	8	8
R^2	0.89	0.891	0.893
Country effects	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes

Standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1. This table shows the regression results where REN_RQ is the interaction of renewable energy consumption and Regulatory Quality; REN_RL is the interaction of renewable energy consumption and Rule of Law; REN_GE is the interaction of renewable energy consumption and Government Efficiency

Appendix Table 8: Robustness checks results (Random effects models and GDI models)

Variables	Baseline random effects	Model 4 fixed effects	Random effects
	GII	GDI	GDI
REN	0.00179***	0.000512	−0.000311
	(0.000191)	(0.000506)	(0.000464)
FDI	−0.000179	9.60e-05	−0.000901
	(0.000424)	(0.000226)	(0.000571)
TO	0.000461***	0.000230***	0.000130
	(0.000168)	(5.96e-05)	(0.000124)
RQ	−0.000547*	0.00147***	0.000595
	(0.000293)	(0.000186)	(0.000608)
lnGDPpc	0.0119	0.00693	0.00171
	(0.00737)	(0.00611)	(0.0122)
lnODApc	−0.00530	0.000439	0.0223***
	(0.00408)	(0.00310)	(0.00711)
AE	9.16e-05	0.000328	0.000496
	(0.000228)	(0.000246)	(0.000383)
Constant	0.391***	0.727***	0.782***
	(0.0414)	(0.0587)	(0.0821)
Observations	160	160	160
Number of id	8	8	8
Overall R^2	0.91	0.82	0.80
Country Effects	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes

Robust standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1